2A93-31

FORECAST OF THE PACIFIC HERRING BIOMASS
IN TOGIAK DISTRICT, BRISTOL BAY, 1991

By

Katherine A. Rowell

and

Linda K. Brannian

Alaska Department of Fish and Game
Division of Commercial Fisheries Management and Development
333 Raspberry Rd
Anchorage, Alaska 99518

October 1993

AUTHORS

Katherine A. Rowell is Region II Togiak Herring Research Biologist for the Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, 333 Raspberry Rd., Anchorage Alaska 99518.

Linda K. Brannian is Region II Regional Biometrician for the Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, 333 Raspberry Rd., Anchorage Alaska 99518.

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The 1990 Togiak District spawning migration consisted of 218 million Pacific herring *Clupea pallasi* weighing 88,105 tons. A total of 13,128 tons was harvested by the inshore sac roe fishery and Dutch Harbor food-and-bait fishery. The 1991 spawning biomass of herring in the Togiak District is forecast to be 54,772 tons. An estimated 52.1% of the population and 59.5% of the biomass will be age 10 or older. The average size of an individual is expected to be 380 g. The 1977 and 1978 year classes that have dominated the biomass since 1983 are expected to contribute 17% of the population and 21% of the biomass.

The 1991 recommended total allowable harvest is 10,954 tons and represents 20% of the forecasted biomass. In accordance with the Bering Sea herring management plan, the allocation would be 1,500 tons of herring for the Togiak District spawn-on-kelp fishery, 662 tons for the Dutch Harbor food-and-bait fishery, and 8,793 tons for the Togiak District sac roe fishery.

INTRODUCTION

The Togiak District of Bristol Bay, Alaska extends from Cape Constantine to Cape Newenham (ADF&G 1990a) and supports the largest spawning population of Pacific herring *Clupea pallasi* in the eastern Bering Sea (Figure 1). Though studies have yet to demonstrate genetic variation among spawning populations of herring in the eastern Bering Sea, differences in growth due to environmental influences are apparent. Herring that spawn in the Togiak District are most similar to herring from the Security Cove and Goodnews Bay Districts but show significant differences in growth and run timing from herring which spawn along the Alaska Peninsula and north of Kuskokwim Bay (Barton 1978, Wespestad and Barton 1981, Walker and Schnepf 1982, Rogers et al. 1983, 1984, Schnepf 1984, Rogers and Schnepf 1985). Herring move into the Togiak District from their overwintering grounds near the Pribilof Islands in the spring to spawn (Shaboneev 1965). After spawning, these herring undertake a feeding migration southward along the Alaska Peninsula, concentrate in the vicinity of Unalaska Island, and return to their overwintering grounds in the fall (Shaboneev 1965, Rumyantsev and Darda 1970). These herring are harvested at various points during their migration, the primary harvest occurs in the Togiak District by a sac roe fishery during the spring (Table 1). Catches since 1978 have ranged from 2,536 to 24,352 tons. Lesser harvests are taken during the summer months in the Dutch Harbor food-and-bait fishery and as bycatch of the domestic pollock trawl fishery.

Beginning in late April the nearshore area of Togiak District is surveyed daily from small aircraft to monitor relative abundance, distribution, and spawning of Pacific herring. Biomass estimates are derived from the number and size of herring schools observed during these surveys (Lebida and Whitmore 1985). Use of aerial surveys to estimate the Togiak herring spawning biomass began in 1978. Observed abundance has ranged from 242,298 tons[1] in 1979 to 76,960 tons in 1980 (Figure 2). The 1980 biomass was probably underestimated due to the poor survey conditions experienced that season.

Year class strength of Togiak herring, as represented by abundance of 5-year-old herring, has varied greatly between 1971 and 1985 (Figure 3). The 1974 year class was the largest in this series and contributed 586 million 5-year-old recruits to the 1979 biomass. Strong recruitment was last detected in 1982 and 1983 when the 1977 and 1978 year classes representing 197 and 189 million age-5 fish joined the spawning biomass. Year class strength of age-5 herring has since averaged 12.5 million fish annually.

The purpose of this report is to provide a forecast of herring returning to spawn in the Togiak District, Bristol Bay in 1991. Specific objectives are (1) to document data sources and forecast methodology, (2) to document and evaluate the performance of historic forecasts, and (3) to present the forecast and, through application of the Bristol Bay herring management plan (ADF&G 1990a), propose a harvest guideline for the 1991 season.

METHODS

The 1991 Togiak herring biomass was projected from the 1990 unharvested spawning biomass (escapement), adjusting for growth, mortality, and recruitment.

---

[1] Tons = 2,000 pounds and is often referred to as short tons. Tonnes = 2,204.62 pounds or 1,000 kg.

Components necessary to prepare a forecast include (1) estimates of the spawning biomass and commercial harvests, (2) age composition of the spawning biomass and harvest, (3) estimates of weight-at-age from an age-weight relationship, (4) age-specific rates of natural mortality, and (5) availability or recruitment by age.

Biomass Estimation

Biomass estimates of herring in the Togiak District are attained through aerial assessment of herring schools (Lebida and Whitmore 1985). The location, number, and size of herring schools observed during aerial surveys are recorded by index area throughout the fishing district. Climatological and survey conditions are also noted for each survey. In past years surveys have been flown by both helicopter and fixed wing aircraft twice daily, usually at low tide. Cumulative herring school surface area is multiplied by depth specific conversion factors to attain a biomass estimate for the surveyed index area. The biomass estimate for a given survey is the summation of index area estimates for that flight. Aerial survey data are calibrated through capturing and weighing herring schools for which the biomass and surface area has been estimated from the air.

Movement and residence time of herring schools on the fishing grounds has not been studied. Therefore, in addition to surveillance by aerial surveys, the population is monitored for changes in age composition and gonad maturity to indicate whether herring are entering or exiting the district. Data for peak biomass estimates, bases on run timing, age, and maturity information, are adjusted for harvests and summed to attain the final biomass estimate or total inshore return. The unharvested biomass or escapement becomes the total inshore return minus all commercial harvests.

Togiak District sac roe harvest figures were taken from the postseason preliminary summary (ADF&G 1990b) and may change when fish tickets are edited and finalized. The Dutch Harbor food-and-bait harvest represented the cumulative catch in August 1990 reported by the assistant area management biologist (A. Quimby, Alaska Department of Fish and Game, Kodiak, personal communication). An estimate of herring bycatch from the domestic pollock trawl fishery was not available.

Age Composition

The age composition of the 1990 herring spawning population was estimated from herring sampled from commercial fishery harvests as well as from areas where significant biomass sightings were obtained within Togiak District. During fishery closures, volunteered commercial and departmental vessels made multiple purse seine or variable mesh gillnet sets to capture herring throughout the duration of the spawning migration. Samples were pooled across three day periods, whenever possible, to obtain sample sizes large enough to represent the estimated biomass within each fishing section. For commercial harvest, samples were collected from tenders and fishing boats for each gear type and fishing section at the close of each fishing period. Herring from both test fishing and commercial harvest samples were used to obtain data on age, size, and gonad condition.

Historical estimates of the peak spawning biomass, by age class, were reconstructed for 1978-1989 using the same methods applied in 1988 (Brannian and Rowell 1989 and Rowell and Brannian 1989). An attempt was made to obtain sample sizes of 200-400 fish from each strata. Only AWL samples collected from purse seine and variable mesh gillnets were used. Biomass observations used for the

peak estimate were stratified by commercial fishing section (Figure 1). AWL data bracketing the peak date, spanning up to a week, were used to estimate age class composition in each section.

Growth

Age-specific instantaneous growth rates (G_i) were used to forecast the 1991 spawning biomass. Weight at age estimates were obtained from Baker (1991) who used Schnute's (1981) general growth model:

$$W_i = W_\infty e^{-e^{-g(i-i_o)}} ,$$
(1)

where W_i is the estimated weight at age i, W_∞ is asymptotic weight, g is a relative growth parameter, and i_o is an initial age parameter. This relationship was fit using a non-linear least squares estimation procedure employing a modified Marquardt algorithm. Mean weight at age data from 1980-1989 Togiak commercial purse seine fishery samples were used to estimate model parameters. The resulting weight-age relationship was:

$$W_i = 515 \, e^{-e^{-0.254(i-4.63)}} .$$
(2)

Growth rates were estimated for ages 3-17 as:

$$G_i = \ln(\frac{W_{i+1}}{W_i}) .$$
(3)

Natural Mortality and Availability

Since natural mortality is thought to increase with age (Vetter 1988), age-specific instantaneous rates of natural mortality and availability were used to forecast the 1991 spawning biomass. Availability is defined as the proportion of a cohort that migrates inshore to spawn in any given year and that will be available to inshore sac roe fisheries. This assumes that juveniles do not migrate inshore with sexually mature herring. Baker (1991) used biomass estimates from 1980-1989 aerial surveys to estimate natural mortality, including availability, as:

$$M_{y,i} = -\log(\frac{N_{y+1,i+1}}{N_{y,i}-C_{y,i}}) ,$$
(4)

where $M_{y,i}$ is natural mortality in year y at age i, $N_{y,i}$ is the number of age i herring in the spawning population in year y, and $C_{y,i}$ is the number of herring of age i in the commercial harvest in year y. This relationship assumes catch was taken over a short period. Fishing time for herring in the Togiak District has declined from 26 d in 1981 to less than 3 d in recent years.

An average natural mortality was then calculated for each age across all years.

Since a linear trend was evident for ages 4 through 14, a linear regression model was fit through these averages as:

$$M_i = -1.588 + 0.205\,i ,\qquad\qquad\qquad (5)$$

with 9 df and R^2 of 0.854. Estimates of mortality became positive at age 8, so herring were assumed to be fully recruited ($A_i=1$) at this age. Equation 5 was used to estimate M_i for herring ages 8-17, even though data for ages 15-17 were not used to fit the equation. Since mortality was confounded with estimates of availability, model values for ages 4-7 were a combination of mortality and availability and designated as availability (A_i). Full recruitment at age 8 assumed by Baker (1991) may be a result of our inability to assess and sample younger herring in the later stages of the run due to poor weather conditions. Full maturity by age 6 has been documented on overwintering grounds (Wespestad 1982).

Forecast of Inshore Return

Each year class present in the 1990 total run biomass was projected forward one year to forecast the return of that year class in 1991 as:

$$B_{1991,i+1} = (B_{1990,i}\,e^{-A_{1990,i}} - C_{1990,i})\,e^{A_{1991,i+1} + G_i - M_i}\qquad\qquad (6)$$

where:

$B_{1991,i+1}$	= 1991 projected biomass for age i+1
$B_{1990,i}$	= 1990 spawning biomass for age i
$A_{1990,i}$	= Availability in 1990 of age i
$A_{1991,i+1}$	= Availability in 1991 of age i+1
G_i	= Instantaneous rate of growth for age i
M_i	= Instantaneous rate of natural mortality for age i

The total 1991 forecasted biomass was the sum of individual, age-specific biomass projections.

Harvest Projection

Harvest levels for 1991 commercial fisheries targeting on herring which spawned in Togiak District were set by the Alaska Board of Fisheries, Bering Sea Herring Management Plan (AAC 27.060) and Bristol Bay Herring Management Plan (AAC 27.865). These regulatory plans specify a maximum exploitation rate of 20%, and a minimum total biomass of 35,000 tons on the grounds before commercial harvest can occur (ADF&G 1990a). Before opening the sac roe fishery, approximately 1,500 tons of herring are set aside for the Togiak District herring spawn-on-kelp harvest, and 7% of the remaining available harvest is set aside for the Dutch Harbor food-and-bait fishery. The remaining harvestable surplus is allocated to the sac roe fishery by gear type: 25% for the gillnet fleet and 75% for the purse seine fleet. In years when circumstances prevent adequate biomass assessment during the season, the fishery harvest will be based solely on the pre-season forecast. Should a manageable separation of the year classes occur, a harvest of up to 20% of the younger age classes (age 4 years or less) may be allowed if at least 20,000 tons of these younger herring are present in the district.

RESULTS AND DISCUSSION

The 1990 Togiak District spawning migration consisted of 218 million herring with a total weight of 88,105 tons (Table 2). The biomass estimate was the sum of (1) the peak biomass estimate on May 8, consisting mainly of age-9 and older herring, (2) the biomass estimated on May 12, consisting mainly of herring age 8 and younger, and (3) the biomass estimated from several partial surveys performed during the remainder of the season (Table 3). For the first time since 1978, age composition and biomass were monitored on the grounds after field camps were dismantled. Herring were observed on the grounds from May 31 through June 4. Data from these surveys were not included in either revised biomass or age composition estimates since we were not sure how many of these herring had been observed earlier in the season. Postseason data are not available for past years, and residence time of herring once they enter the grounds has not been determined.

Age-9 and older herring represented 79.2% of the total biomass and 73.2% of the total number of individuals in the 1990 spawning run. The 1978 year class made the greatest contribution to the 1990 biomass. These age-12 herring represented 27.1% of the total population in biomass and 23.3% in numbers. Recruitment of age-3 and -4 herring represented less than 0.2% of the biomass and 0.4% of the individuals in the population. The number of 5-year-old herring (1985 year class) totaled 1.2 million, which was small in comparison to historical abundance of this age class (Figure 3). A total of 13,128 tons of Togiak herring was harvested by all fisheries. An estimated 74,977 tons remained after harvests by the sac roe and food-and-bait fisheries were removed from the spawning biomass.

The total inshore return estimate for 1990 was nearly 1.6 times greater than the 56,020 tons forecasted from the 1989 escapement (Rowell and Brannian 1989). In general, the proportion of younger aged herring (age 6 and 7) was less than that forecasted, while the proportion of older aged herring (age 12 and 13) observed was greater than that forecasted (Figure 4). Therefore, the overall forecast error of 57% was not due to an unanticipated recruitment of younger age classes ($\leq$ age 6), but rather to a larger than expected return of older age classes ($>$ age 9)(Figures 5 and 6). A forecast error of this type could have occurred if the abundance estimate for 1989 was too low, estimate for 1990 was too high, or estimates of natural mortality for older herring were too high. The difference between the forecasted and observed population for 1990 could also have resulted from sampling bias in data used to determine age composition of the biomass for the 1989 season. For example, samples may have over represented older aged herring in the spawning migration since sampling was limited, due to poor weather conditions, later in the season when younger aged herring are generally most abundant.

The 1991 forecast of spawning herring biomass for Togiak District is 54,772 tons (Table 2, 4). The average size of an individual is expected to be 380 g. An estimated 52.1% of the individuals and 59.5% of the biomass are expected to be age 10 or older in 1991 (Figure 7 and 8). The contribution of the 1977 and 1978 year classes, returning as age-13 and age-14 herring, is expected to decrease to 21% of the total biomass since natural mortality rates increase for these older aged herring. Cohorts which are also expected to make large contributions to the 1991 run are the 1983 (age 8), 1981 (age 10), and 1984 (age 7) year classes, which should account for respectively 22%, 21%, and 14% of the total biomass (Figures 7 and 8).

In past years, older herring have arrived on the fishing grounds before the younger and newly recruited age classes. The fishery and therefore, biomass assessments have been directed towards these older herring. Temporal separation of older and younger age classes while useful for management has resulted in little information being collected on younger and later arriving herring.

Forecasts for the youngest age classes (age 3 and 4), which are not fully recruited, are incomplete and constitute a source of forecast error. The Togiak herring forecast has been less than the observed biomass since 1984 (Figure 9), and average forecast error (1984-90) has been 30%.

For 1991, the total allowable harvest based on the forecast is 10,954 tons (20% of forecasted biomass). In accordance with existing management plans, the allocation would then be 1,500 tons for the Togiak District spawn-on-kelp fishery, 662 tons for the Dutch Harbor food-and-bait fishery, and 8,793 tons for the Togiak District sac roe fishery.

LITERATURE CITED

Alaska Department of Fish and Game (ADF&G). 1988. Annual management report, 1987, Bristol Bay area. Alaska Department of Fish and Game, Division of Commercial Fisheries, Region II, unpublished report, Anchorage.

Alaska Department of Fish and Game (ADF&G). 1990a. Commercial herring fishing regulations (1990 Edition). Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau.

Alaska Department of Fish and Game (ADF&G). 1990b. Togiak District herring and spawn on kelp preliminary summary, 1990. Alaska Department of Fish and Game, Division of Commercial Fisheries, Region II, unpublished report, Anchorage.

Alaska Department of Fish and Game (ADF&G). 1991. Annual management report, 1990, Bristol Bay area. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A91-01, Anchorage.

Baker, T.T. 1991. Cohort analysis of Pacific herring in the Togiak District, Alaska, 1980-90. Proceeding of the International Herring Symposium, Lowell Wakefield Fisheries Symposium, University of Alaska, Alaska Sea Grant Program Report 91-01, Fairbanks.

Barton, L.H. 1978. Finfish resource surveys in Norton Sound and Kotzebue Sound. U.S. Dept. Comm. and U.S. Dept. Interior Environmental Assessment of the Alaskan Continental Shelf, Final Report, Biological Studies 4:75-313.

Brannian, L.K. and K.A. Rowell. 1989. Forecast of the Pacific herring biomass in Togiak District, Bristol Bay, 1989. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2D89-07, Anchorage.

Lebida, R.C. and D.C. Whitmore. 1985. Bering Sea herring aerial survey manual. Alaska Department of Fish and Game, Division of Commercial Fisheries Bristol Bay Data Report No.85-2, Anchorage.

Rogers, D. E. and K.N. Schnepf. 1985. Feasibility of using scale analysis methods to identify Bering Sea herring stocks. Fisheries Research Institute, University of Washington, Annual Report FRI-UW-8501, Seattle.

Rogers, D.E., N.N. Schnepf and P.R. Russell. 1983. Feasibility of using scale analysis methods to identify Bering Sea herring stocks. Fisheries Research Institute, University of Washington, preliminary report to the U. S. Department of Commerce, NOAA, National Marine Fisheries Service, Seattle.

Rogers, D.E., N.N. Schnepf and P.R. Russell. 1984. Feasibility of using scale pattern analysis methods to identify Bering Sea herring stocks. Fisheries

Research Institute, University of Washington, Annual Report FRI-UW-8402, Seattle.

Rowell, K.A. and L.K. Brannian. 1989. Forecast of the Pacific herring biomass in Togiak District, Bristol Bay, 1990. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2D89-11, Anchorage.

Rumyantsev, A.I. and M.A. Darda. 1970. Summer herring in the eastern Bering Sea. IN: Soviet fisheries investigations in the northeastern Pacific, P.A. Moiseev, ed., Part V: 409-41. (Trans. 1972, Israel Prog. Sci. Trans.)

Sandone, G.J. and L.K. Brannian. 1988. Estimated age-class contribution of Pacific herring to the commercial sac-roe harvests of Togiak District, 1980-1987. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A88-12, Anchorage.

Schnepf, K.N. 1984. Stock separation of eastern Bering Sea herring (*Clupea harengus pallasi*) with scale pattern analysis. M. S. thesis. School of Fisheries, University of Washington, Seattle.

Schnute, J. 1981. A versatile growth model with statistically stable parameters. Canadian Journal of Fisheries and Ocean Sciences 38:1128-1140.

Shaboneev, I.E. 1965. Biology and fishing of herring in the eastern part of the Bering Sea. In: Soviet fisheries investigations in the northeastern Pacific, P.A. Moiseev, editor, Part IV: 130-54. (Trans. 1968. Israel Prog. Sci. Trans.)

Walker, R.V. and K. N. Schnepf. 1982. Scale pattern analysis to estimate the origin of herring in the Dutch Harbor fishery. Fisheries Research Institute, University of Washington, Final Report FRI-UW-8219, Seattle.

Wespestad, V.G. 1982. Cohort analysis of catch data on Pacific herring in the eastern Bering Sea, 1959-81. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Technical Memorandum NMFS F/NWC-24, Seattle.

Wespestad, V.G. and L.H. Barton. 1981. Distribution, biology and stock assessment of Pacific herring. In: The eastern Bering sea shelf: Oceanography and Resources, Vol.I. [D.W. Hood and J. A. Calder, editors]. U.S. Department of Commerce, NOAA, Office of Marine Pollution Assessment, Juneau.

Vetter, E.F. 1988. Estimation of natural mortality in fish stocks: A review. NMFS, Fishery Bulletin: Vol. 86, No.1. 25-42.

Table 1. Total inshore run and commercial harvests for Togiak herring, 1968-1990.

Year	Total Biomass in Tons [a]	Harvest in Tons		
		Togiak Sac Roe [b]	Togiak Spawn-on-Kelp [c]	Dutch Harbor Food and Bait [d]
1968		82	2	
1969		43	5	
1970		25	18	
1971		31	23	
1972		73	29	
1973		46	5	
1974		112	57	
1975		51	50	
1976			134	
1977		2,536	125	
1978	191,450	7,016	150	
1979	242,298	10,485	188	
1980	76,960	22,288	86	
1981	158,860	11,353	172	704
1982	98,022	19,837	107	3,565
1983	141,053	24,352	122	3,567
1984	113,471	17,654	184	3,578
1985	132,420	23,466	31	3,480
1986	94,390	14,796	170	2,394
1987	89,086	14,117	139	2,503
1988	134,717	14,382	245	2,004
1989	98,965	12,258	280	3,084
1990	88,105	12,307 [e]	207	821

[a] Brannian and Rowell (1989) through 1988, Rowell and Brannian (1989) for 1989.

[b] Data source: Sandone and Brannian (1988) through 1987 and ADF&G (1991) for 1989-1990.

[c] Data source: ADF&G (1988) through 1987 and ADF&G (1991) thereafter.

[d] Data source: Len Schwarz, personal communication, 1988 through 1988 and A. Quimby thereafter. Fishery did not occur from 1946 through 1980.

[e] Data source: Preliminary season summary (ADF&G 1990b)

Table 2. Year class composition of the 1990 Togiak herring harvest, escapement, and total run biomass, and forecasted biomass for 1991.

		1990 Harvest (tons)				1990 Escapement (tons)	1990 Total Run				1991 Togiak Projected Herring Biomass					
Year Class	Age Class	Sac Roe[a] P.Seine	G.Net	Food/Bait Harvest	Total (tons)		Biomass (tons)	No.of Fish (* 1,000)	% by Wt.	% by No.	Year Class	Age Class	Biomass (tons)	No.of Fish (* 1,000)	% by Wt	% by No.
1989	1	0	0	0	0	0	0	0	0.0	0.0						
1988	2	0	0	0	0	0	0	0	0.0	0.0	1989	2	0	0	0.0	0.0
1987	3	0	0	0	0	46	46	335	0.1	0.2	1988	3	0	0	0.0	0.0
1986	4	3	0	0	3	66	69	412	0.1	0.2	1987	4	238	1,364	0.4	1.0
1985	5	26	5	0	31	225	256	1,158	0.3	0.5	1986	5	112	486	0.2	0.4
1984	6	401	130	11	542	4,824	5,366	19,463	6.1	8.9	1985	6	384	1,361	0.7	1.0
1983	7	988	351	36	1,375	8,210	9,585	28,748	10.8	13.2	1984	7	7,721	23,271	14.1	17.8
1982	8	304	136	20	460	2,579	3,039	8,013	3.4	3.7	1983	8	12,015	31,964	21.9	24.5
1981	9	1,695	547.	78	2,320	12,248	14,568	38,392	16.5	17.6	1982	9	1,734	4,194	3.2	3.2
1980	10	611	189	26	826	5,095	5,921	14,165	6.7	6.5	1981	10	11,731	26,342	21.4	20.1
1979	11	1,453	519	177	2,149	11,515	13,664	32,242	15.5	14.8	1980	11	2,391	5,079	4.4	3.9
1978	12	2,681	725	279	3,685	20,149	23,834	50,839	27.1	23.3	1979	12	6,862	13,957	12.5	10.7
1977	13	947	355	151	1,453	9,179	10,632	21,641	12.1	9.9	1978	13	9,344	18,387	17.1	14.1
1976	14	78	55	26	159	567	726	1,773	0.8	0.8	1977	14+	2,240	4,310	4.1	3.3
1975	15	26	39	17	82	164	246	482	0.3	0.2	1976					
1974	16+	32	11	0	43	110	153	232	0.2	0.1	1975					
Total		9,245	3,062	821	13,128	74,977	88,105	217,909	100.0	100.0			54,772[b]	130,715	100.0	100.0

[a] Preliminary harvest data.

[b] Predicted mean weight of the fish is 380 grams.

9

Table 3. Daily observed biomass estimates of herring during the 1990 season by index area, Togiak District, Bristol Bay, Alaska[a].

Date	Survey Conditions	Survey Time	Milt Sightings No.	Milt Sightings Length (Mi)	NUS	KUK	MET	NUK	UGL	TOG	TNG	MTG	HAG	OSK	PYR	CN	Daily Total
4/22	Poor	am	0	0.0	-	0	0	0	0	0	0	0	0	0	-	-	0
4/25	Good	am	0	0.0	0	0	0	0	0	0	-	-	-	-	-	-	0
4/28	Good-Fair	pm	0	0.0	-	0	0	0	0	0	0	0	0	-	-	-	0[c]
4/29	Good-Fair	pm	0	0.0	0	0	0	0	0	0	0	0	0	-	-	-	0[c]
4/30	Good	pm	0	0.0	0	0	0	0	0	0	0	0	0	-	-	-	0[d]
5/01	Good	pm	0	0.0	12	0	0	0	0	0	0	0	0	-	-	-	12[e]
5/02	Fair-Poor	pm	0	0.0	0	0	0	0	0	0	0	0	0	0	-	-	0[f]
5/03	Fair-Poor	pm	0	0.0	-	-	0	0	0	0	0	0	0	-	-	-	0[g]
5/04	Good	pm	0	0.0	-	8	0	0	0	0	0	0	0	0	0	-	8[h]
5/05	Fair	am	0	0.0	-	0	0	0	0	0	0	0	-	-	-	-	0[i]
5/07	Good-Poor	pm	1	0.8	-	0	15	15	844	49	586	22,349	12,501	5,382	0	-	41,741
5/08	Fair	am-pm	11	8.3	-	2	12	296	16,694	8,800	12,674	11,395	21,921	85	-	-	71,879[j]
5/09	Poor-Fair	am-pm	63	37.1	-	-	-	-	-	-	-	-	-	-	-	1,610[k]	1,610
5/10	Good-Poor	am-pm	6	3.3	720	6,127	0	144	-	-	-	-	-	-	-	-	6,991[l]
5/11		pm	5	1.7	-	-	-	-	-	-	-	-	-	-	-	-	-
5/12	Fair	pm	2	1.8	17,906	6,058	1,508	264	2,883	19,109	720	778	187	2,452	43	-	51,908
5/13	Poor	pm	0	0.0	-	-	-	74	651	13,888	0	351	93	409	-	105[k]	15,571
5/14	Fair	am-pm	2	2.0	-	1,137	1,892	314	1,088	4,797	0	870	14	15	-	-	10,127
5/14	Good	pm	1	2.0	-	-	2,360	285	0	-	-	-	-	-	-	-	2,645
5/15	Fair	am	1	1.0	-	-	-	66	85	14,526	-	-	-	-	-	-	14,677
5/16	Poor	am	0	0.0	-	0[m]	2	225	15	0[m]	2	-	0[m]	-	-	-	244
5/18	Poor-Unsat.	pm	0	0.0	-	-	0[m]	1,897[m]	92[m]	-	-	-	-	-	-	-	1,989
5/19	Unsatisfactory	am	0	0.0	-	0	0	0	1,345	0	-	-	-	-	-	-	1,345
5/19	Poor	pm	0	0.0	-	-	0[m]	2,423	0[m]	-	-	-	-	-	-	-	2,423
5/20	Poor-Unsat.	am-pm	0	0.0	-	-	-	110	240[m]	-	-	-	-	-	-	-	350
5/21	Poor	am	0	0.0	-	-	-	498	-	-	-	-	-	-	-	-	498
5/25	Poor-Unsat.	pm	0	0.0	0	0	0	0	622	0[m]	-	-	-	-	-	-	622
5/28[n]		pm	1	7.0	-	-	-	-	-	-	-	-	-	-	-	-	-
5/31	Excellent	pm	1	0.7	2,586	866	4,231	2,049	458	5,425	26	71	67	207	0	0	15,986
6/05	Fair	pm	0	0.0	0	679	160	937	250	8,476	2	18	48	15	0	0	10,585
Total			94	65.7													

[a] Togiak District Pacific herring biomass was estimated at 88,105 short tons for the 1990 season. The estimate is derived from summing proportions of peak aerial surveys as depicted by changes in age composition.

[b] Index Areas: NUS- Nushagak Peninsula; KUK-Kulukak; MET-Metervik; NUK-Nunavachak; UGL-Ungalikthluk/Togiak; TOG-Togiak; TNG-Tongue Point; MTG-Matogak; HAG;Hagemeister; OSK-Osviak; PYT-Pyrite Point; CN-Cape Newenham.

Table 3. Continued (page 2 of 2).

c Schools of smelt observed in the District.

d Six tons biomass of smelt observed behind Tongue Point (TNG index area).

e 950 ton biomass of smelt observed in combined TOG, TNG, and MTG index areas.

f 1,151 ton biomass of smelt observed in combined UGL, TOG, TNG, and MTG index areas.

g 565 ton biomass of smelt observed in MTG index area.

h 626 ton biomass of smelt observed in the combined UGL, TNG, MTG, and PYR index areas.

i 1,590 tons of smelt observed in the NUK, UGL, TOG and MTG index areas.

j Peak survey.

k Biomass observed along shoreline of Crooked and High Islands.

l Survey of the NUS to NUK index areas indicated eastward movement of additional biomass.

m Partial Survey.

n Area surveyed 28 May. Biomass estimate not quantified. Significant numbers of schools present in the Nunavachak, Kulukak Bay, and Togiak Bay sections. Significant biomass (narrow band, 15 miles in length,) of herring was observed exiting the District along the Nushagak Peninsula.

11

Table 4. Information used to forecast the herring biomass expected to return to Togiak District in 1991.

Age (i)	Mean Wt.[a] at time (i)	Age Interval	G^b	M^c	A^d	e^{-A}	$A_{(i+1)} - M_i + G$	Age Class	1990 Total Return (tons)	1990 Harvest (tons)	1991 Projection (tons)	% by Weight	Number of Fish (X 1,000)	% by Number
2		2-3		0.000			-2.05	2	0	0			
3	110.0	3-4	0.362	0.000	-2.05	7.745	-0.40	3	46	0	0	0.0	0	0.0
4	158.0	4-5	0.275	0.000	-0.77	2.153	-0.29	4	69	0	238	0.4	1,364	1.0
5	208.0	5-6	0.208	0.000	-0.56	1.754	-0.15	5	256	3	112	0.2	486	0.4
6	256.0	6-7	0.162	0.000	-0.36	1.429	0.01	6	5,366	31	384	0.7	1,361	1.0
7	301.0	7-8	0.125	0.000	-0.15	1.163	0.12	7	9,585	542	7,721	14.1	23,271	17.8
8	341.0	8-9	0.095	0.054	0.00	1.000	0.04	8	3,039	1,375	12,015	21.9	31,964	24.5
9	375.0	9-10	0.074	0.259	0.00	1.000	-0.18	9	14,568	460	1,734	3.2	4,194	3.2
10	404.0	10-11	0.055	0.465	0.00	1.000	-0.41	10	5,921	2,320	11,731	21.4	26,342	20.1
11	427.0	11-12	0.044	0.670	0.00	1.000	-0.63	11	13,664	826	2,391	4.4	5,079	3.9
12	446.0	12-13	0.033	0.875	0.00	1.000	-0.84	12	23,834	2,149	6,862	12.5	13,957	10.7
13	461.0	13-14	0.026	1.080	0.00	1.000	-1.05	13	10,632	3,685	9,344	17.1	18,387	14.1
14+	473.0	14-15	0.019	1.286	0.00	1.000	-1.27	14+	1,125	1,737	2,240	4.1	4,310	3.3
								Total	88,105	13,128	54,772	100.0	130,715	100.0

[a] Weight at time $i = 515 \exp[-\exp^{-0.264(i-4.63)}]$.

[b] Instantaneous growth rate $G = \ln(W_{i+1}/W_i)$.

[c] Instantaneous natural mortality schedule based on the average age-specific mortality for 1980-89.

[d] Availability (A) schedule based on biomass at age data, 1980-1989.

[e] $\text{Projection}_{i,1991} = [\text{Total Return}_{(i,1990)} \exp(-A_i) - C_{i,1990}] \exp(A_{i+1} - M_i + G_i)$.
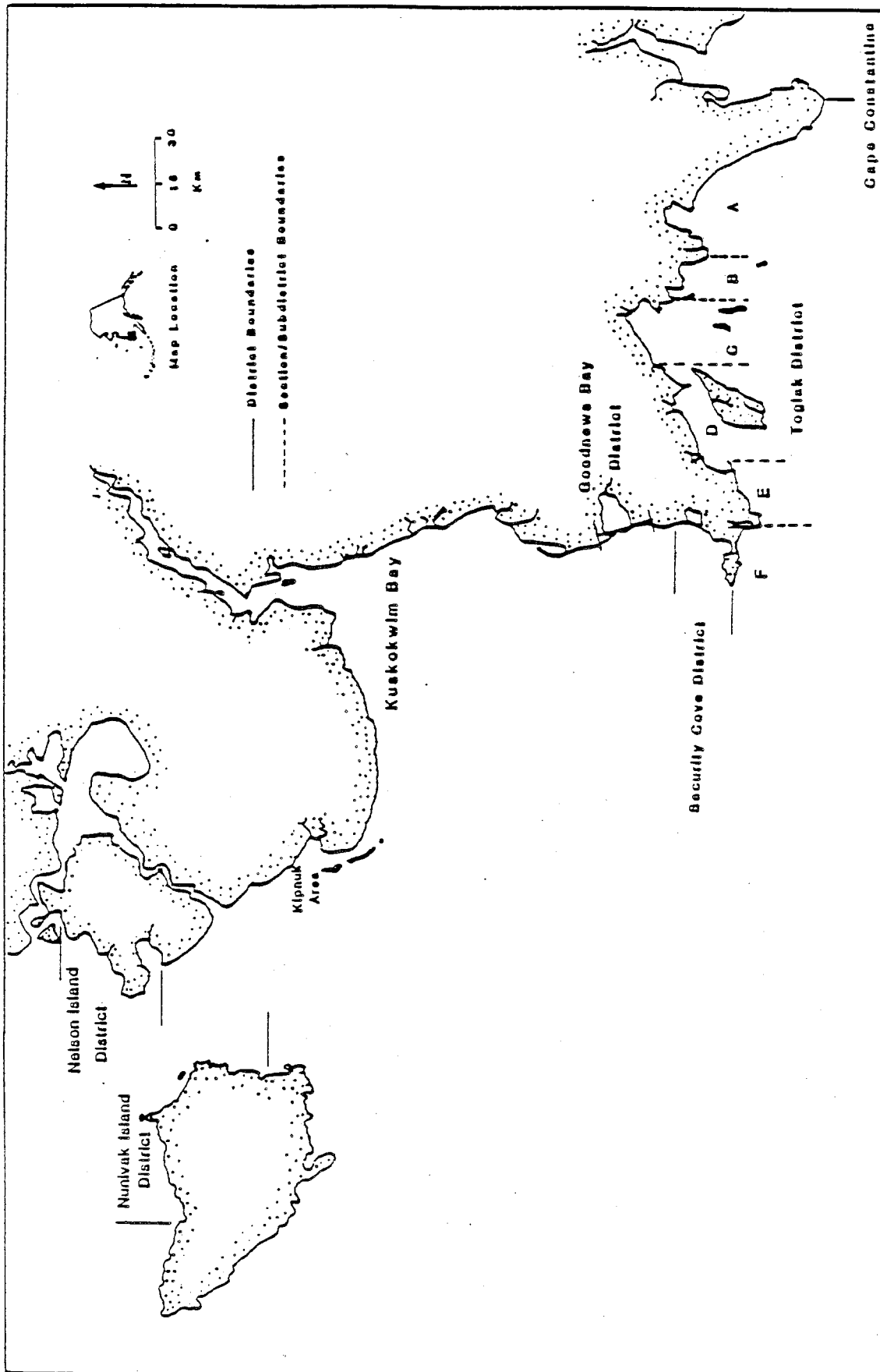
12

Figure 1. Togiak (A = Kulukak, B = Nunavachak, C = Togiak, D = Hagemeister, E = Pyrite Point, F = Cape Newenham Sections), Security Cove, Goodnews Bay, Nelson Island, and Nunivak Island Pacific herring commercial fishing districts, Bering Sea, Alaska.
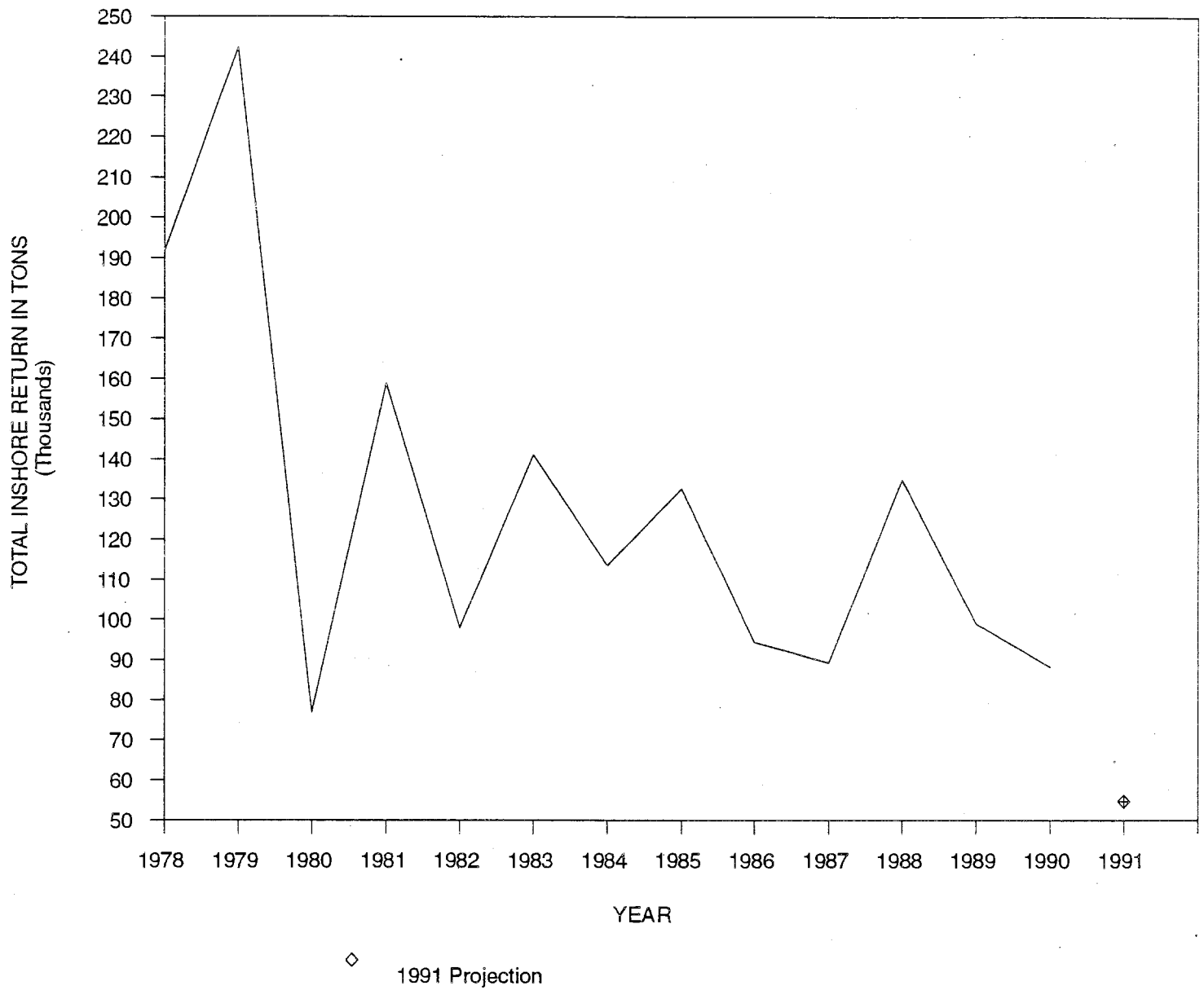
13

Figure 2. Togiak District herring biomass as estimated from aerial surveys. The 1991 biomass
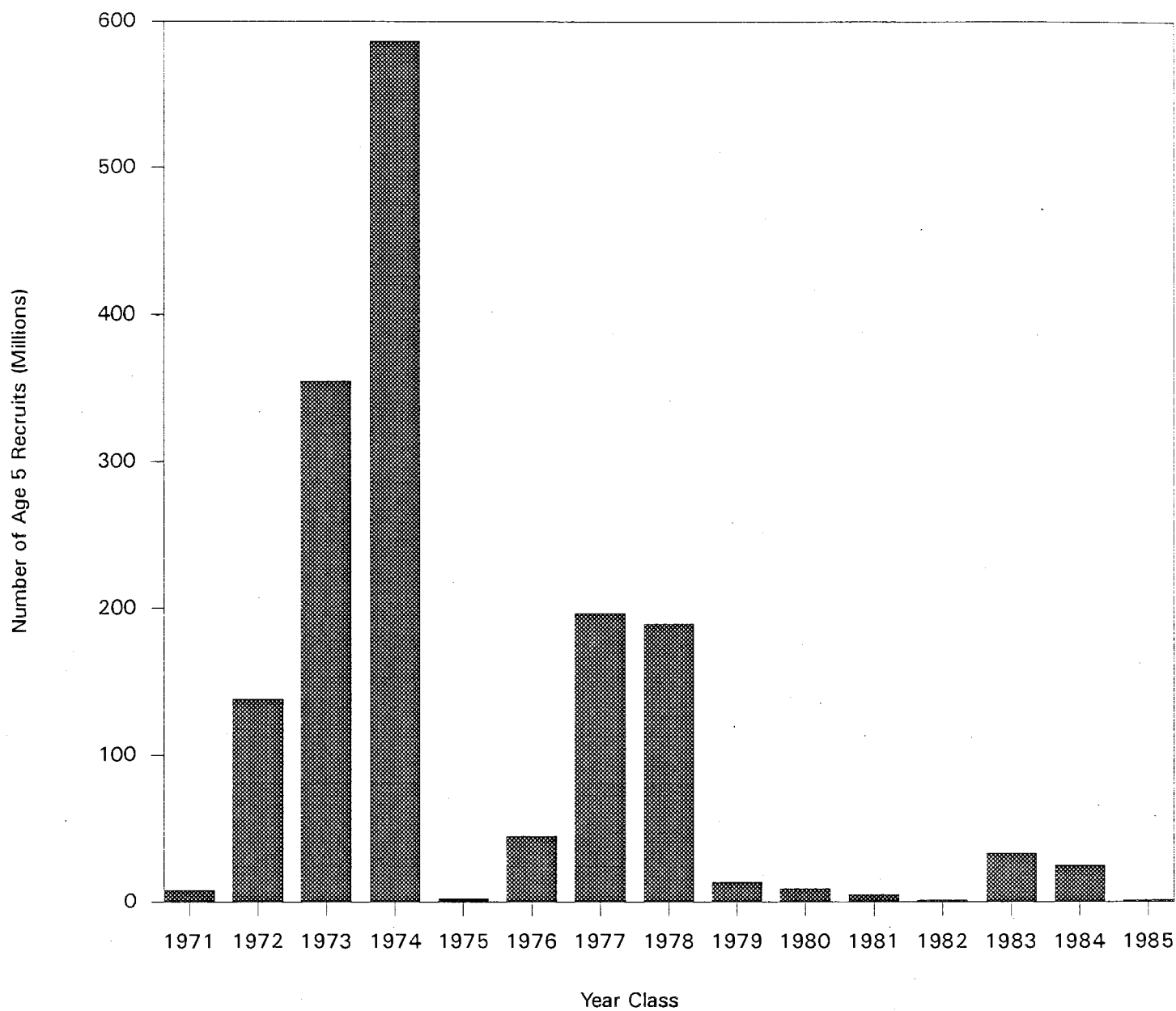(diamond) was projected from the 1990 spawning biomass.

14

Figure 3. Historical year class strength of Togiak District herring in numbers of 5-year-old fish.
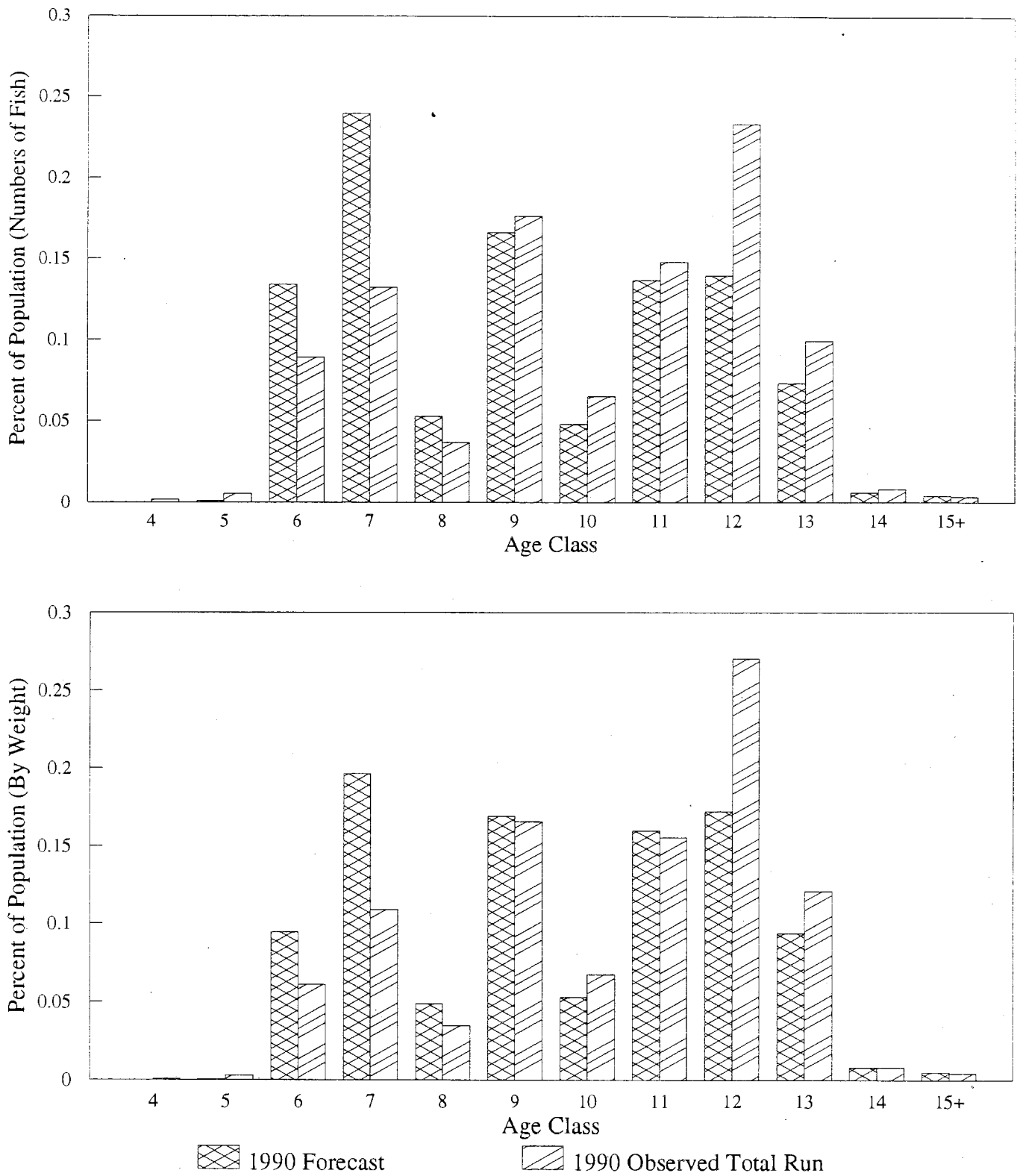
Figure 4. Age composition of the Togiak District herring population in 1990 compared to that projected from 1989 (top is percent in numbers and bottom is tons).
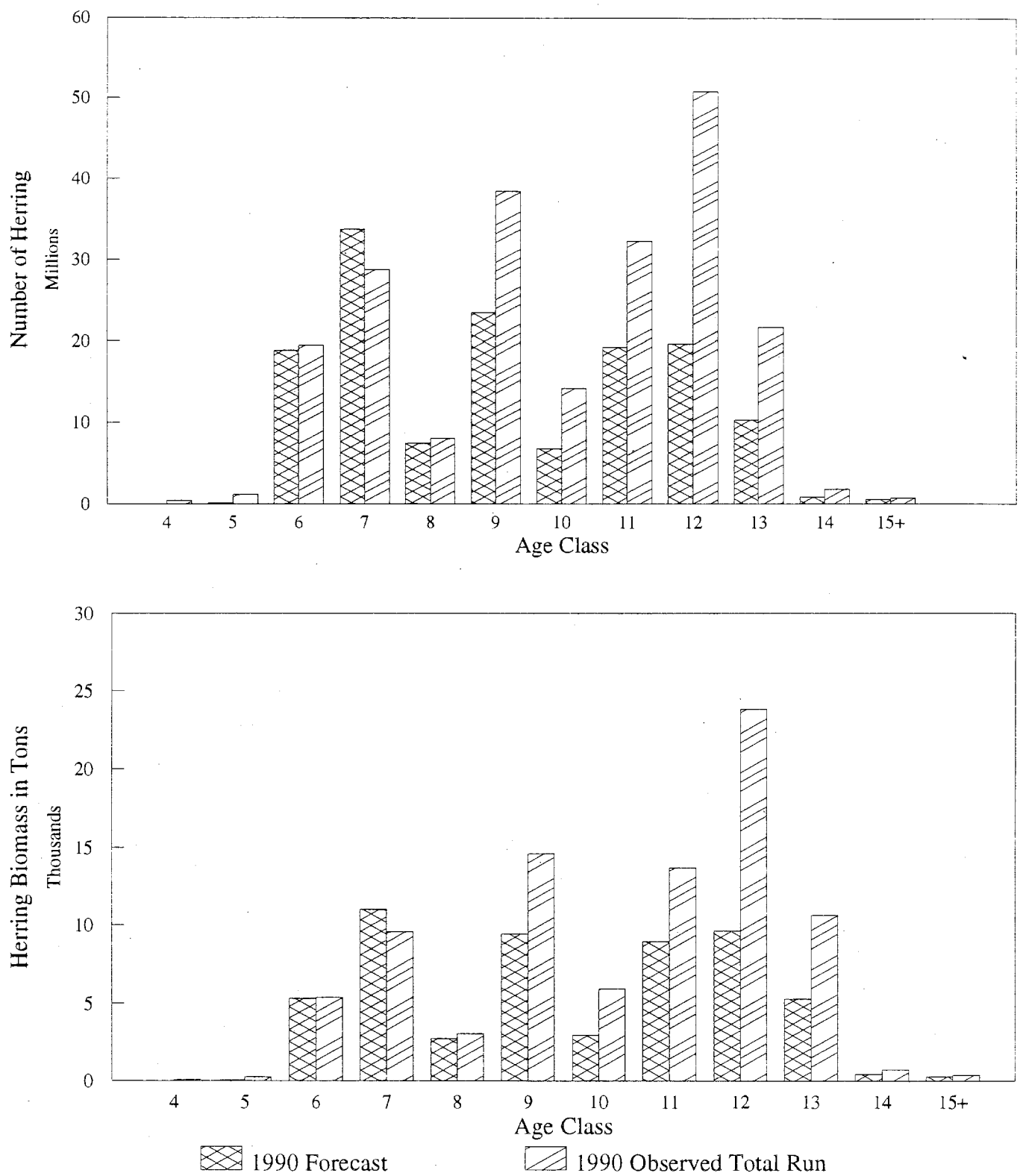
Figure 5. Age class strength in numbers of fish (top) and biomass (bottom) of the Togiak District herring population in 1990 compared to that projected from 1989.
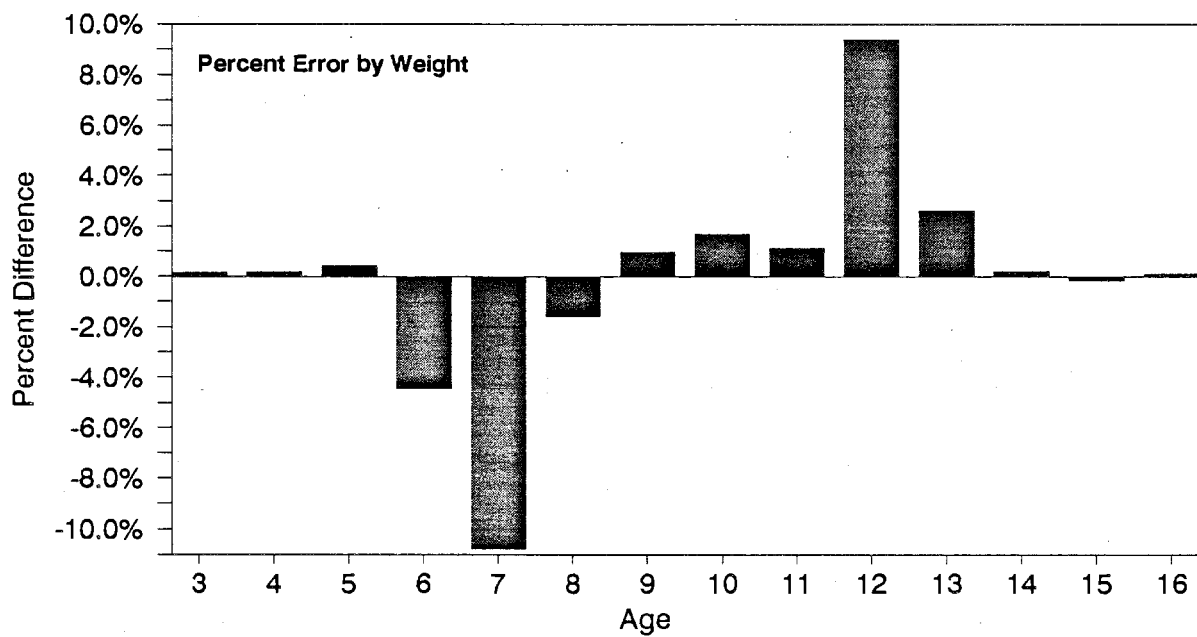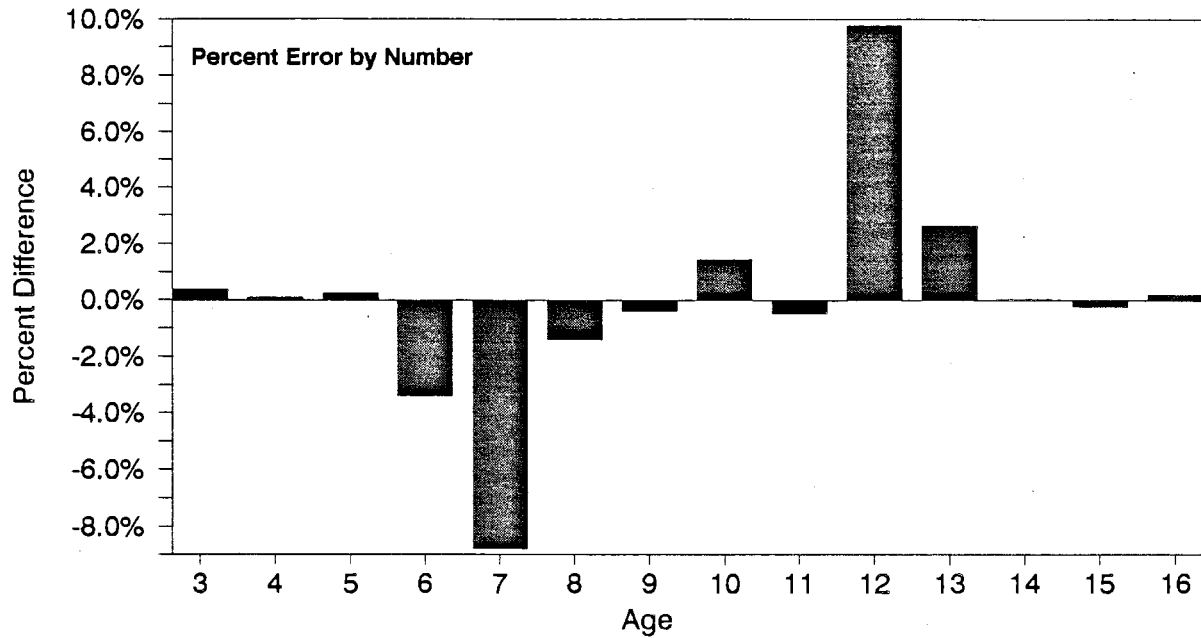
Figure 6. Percent difference by age class in numbers of fish (top) and biomass (bottom) of the Togiak District herring population in 1990 compared to that projected from 1989.
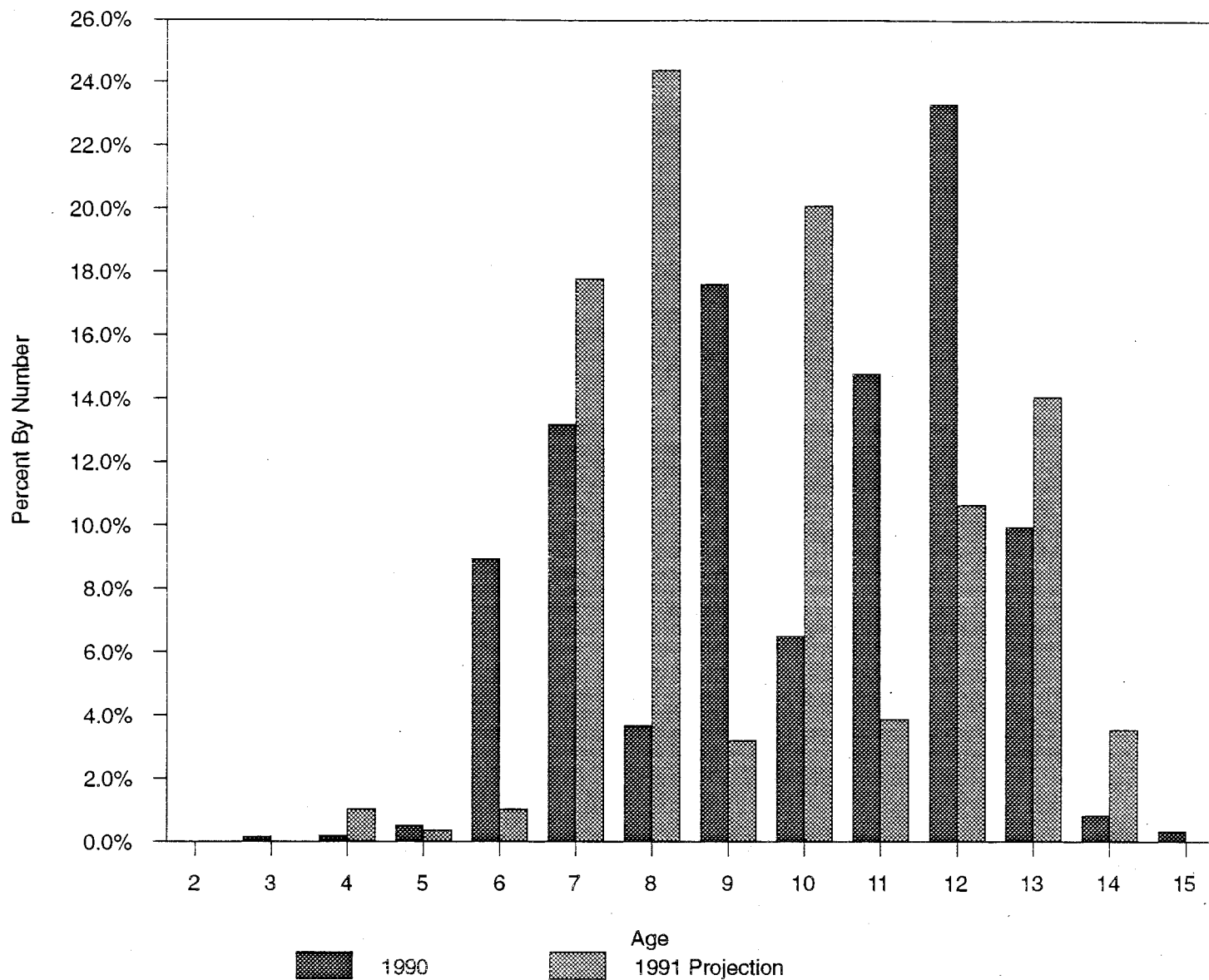
Figure 7. Age composition of the Togiak District herring population in 1990 and projected for 1991.
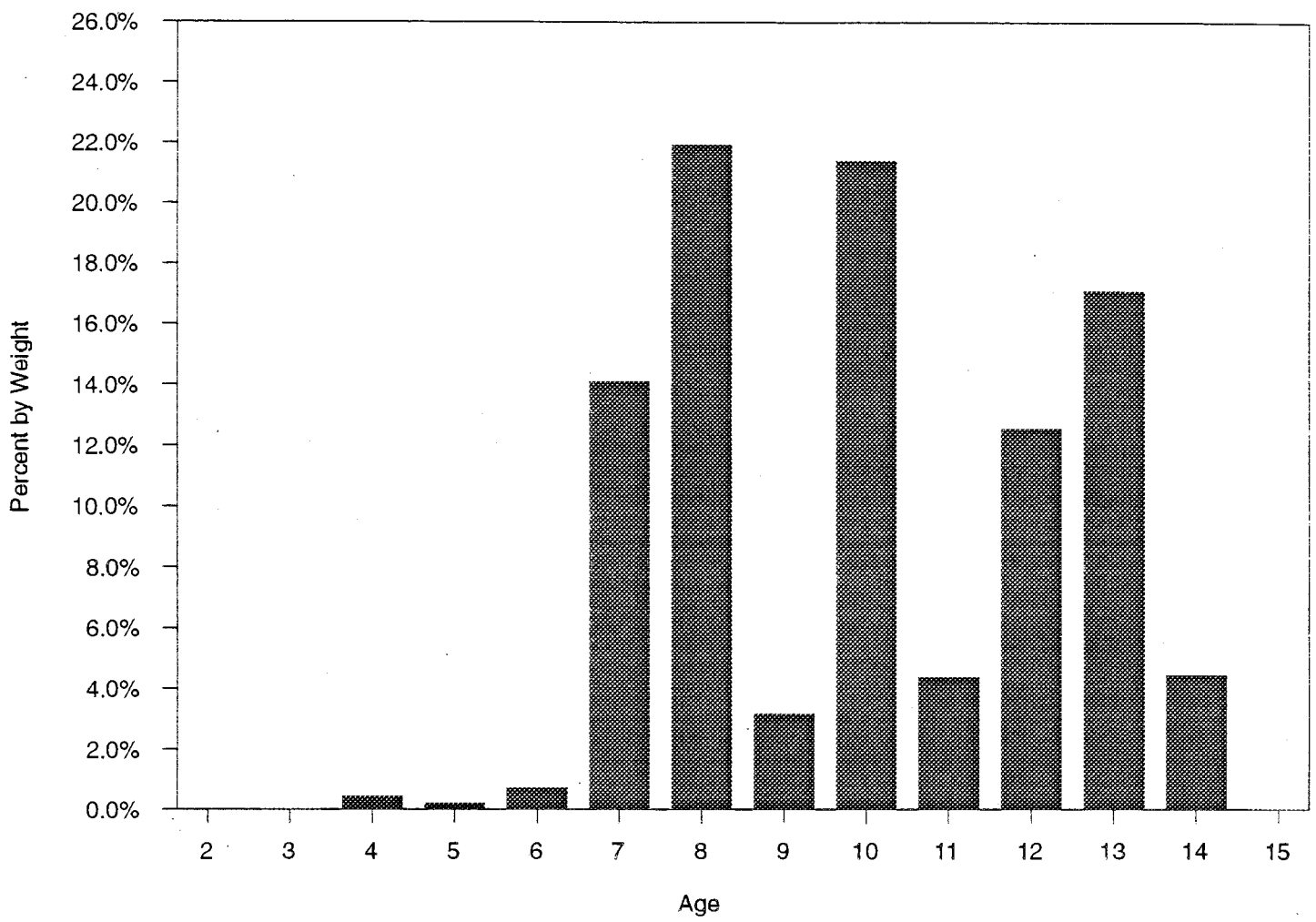
Figure 8. Age distribution by weight of the 1991 biomass forecasted for Togiak District herring. The mean weight is projected at 380 grams.
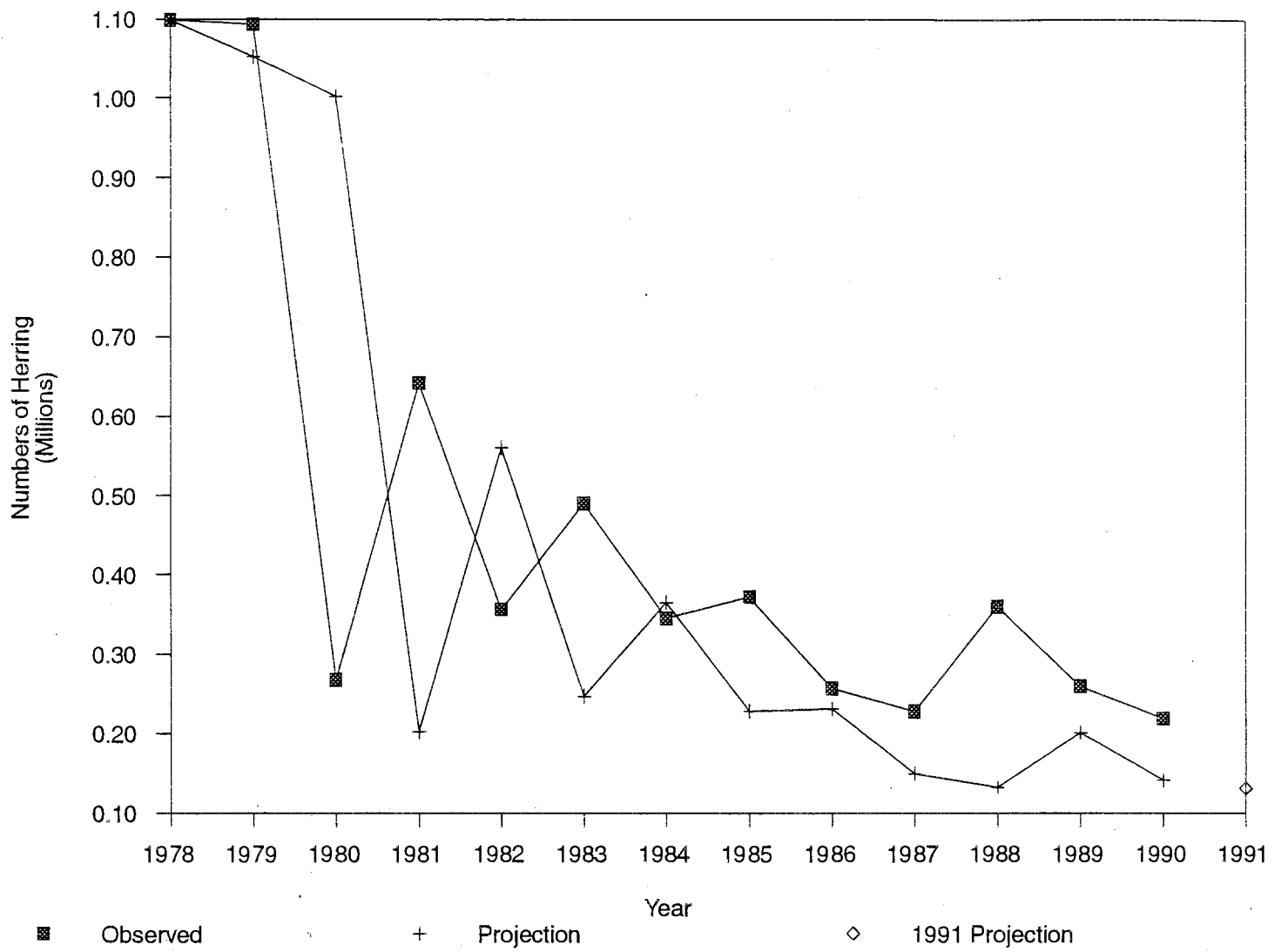
Figure 9. Performance of the Togiak District herring forecast based on a schedule of increasing mortality with age.